SOIL SMaRTS

Specific Management and Resources Trainings for Soil Health in Tennessee

TRAINING CURRICULUM

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Southern SARE
Sustainable Agriculture Research & Education

UT Extension
Institute of Agriculture
The University of Tennessee

USDA United States Department of Agriculture

This curriculum was developed through a Southern SARE grant and collaboration between Tennessee State University, the USDA-NRCS, and the University of Tennessee. The objective of this curriculum is to provide training on soil health and sustainable management practices for soil health to extension agents and local officials so that they may disseminate this information to their stakeholders.

Soil Smarts Training Curriculum

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Appendix

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Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

COVER CROP

Code 340

(Ac)

DEFINITION

Grasses, legumes, and forbs planted for seasonal vegetative cover.

PURPOSE

This practice is applied to support general criteria and one or more of the following purposes:

- Reduce erosion from wind and water.
- Maintain or increase soil health and organic matter content.
- Reduce water quality degradation by utilizing excessive soil nutrients.
- Suppress excessive weed pressures and break pest cycles.
- Improve soil moisture use efficiency.
- Minimize soil compaction.

CONDITIONS WHERE PRACTICE APPLIES

All lands requiring seasonal vegetative cover for natural resource protection or improvement.

CRITERIA

General Criteria Applicable to All Purposes

Plant species, seedbed preparation, seeding rates, seeding dates, seeding depths, fertility requirements, and planting methods will be consistent with applicable local criteria and soil/site conditions. (See Appendix – Table 1, Recommended Cover Crop Mixes or refer to SARE's publication:

http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition.)

Select species that are compatible with other components of the cropping system.

Ensure herbicides used with crops are compatible with cover crop selections and purpose(s).

Cover crops may be established between successive production crops, or companion-planted or relay-planted into production crops. Select species and planting dates that will not compete with the production crop yield or harvest.

Do not burn cover crop residue.

Determine the method and timing of termination to meet the grower's objective and the current NRCS Cover Crop Termination Guidelines.

When a cover crop will be grazed or hayed, ensure that crop selection(s) comply with pesticide label rotational crop restrictions and that the planned management will not compromise the selected conservation purpose(s).

When grazing cover crops, the combined canopy and surface residue will be 90% or greater at all times. The cover crop should reach a minimum height of 10 inches before grazing and grazed no lower than 5 inches. An area must be provided to remove livestock from the cover crop when the cover crop is vulnerable to overgrazing or excessive trampling. The area must be a pasture or a designated sacrifice area away from sensitive areas. See the livestock feeding assessment tool in the TN Graze program to size and site the sacrifice area.

Cover crops will not be managed as a harvested crop.

If the specific rhizobium bacteria for the selected legume are not present in the soil, treat the seed with the appropriate inoculum at the time of planting.

The cover crop will be a minimum of 10" tall or have a biomass of 3000 lb. (300 lb. /ac. In.) at termination.

Additional Criteria to Reduce Erosion from Wind and Water

Time the cover crop establishment in conjunction with other practices to adequately protect the soil during the critical erosion period(s).

Select cover crops that will have the physical characteristics necessary to provide adequate erosion protection.

Use the current NRCS-approved erosion prediction technology to determine the amount of surface and/or canopy cover needed from the cover crop to achieve the erosion objective.

Combined canopy and surface residue cover will be 90 percent or greater during the period of potentially erosive wind or rainfall.

Additional Criteria to Maintain or Increase Soil Health and Organic Matter Content

Cover crop species will be selected on the basis of producing higher volumes of organic material and root mass to maintain or increase soil organic matter. Plant mixtures of legumes with grasses, crucifers, and/or other forbs. A minimum of 5 species will be planted with a total seeding rate of 100% or higher of the full rate. The full seeding rate in the mix should include (1) 10% or more of small grains and legume species components; (2) 5 to 15% brassica or crucifers (for cotton, no brassicas other than optional radish); and, (3) no more than 1.5 lbs. of brassicas are recommended in any mix. If planting after October 1, do not plant radish in the mix.

Species that will terminate by frost or heat (e.g. buckwheat) can make up to 20% of the total seeding rate for the mix.

Cover crops and the following cash crop will be planted no-till. EXCEPTION: Cash crops that have not been traditionally planted no-till (ONLY tobacco, green beans and vegetable crops) may be strip tilled at planting when meeting a STIR value of $\leq$ 20 for each crop in the rotation.

Target a C:N ratio prior to a high residue crop of 30:1 or less.

Target a C:N ratio prior to a low residue crop of 31:1 or higher.

C:N ratio effects nutrient cycling and soil residue cover. If the residue covering the soil is lacking, increase the C:N ratio by increasing the grass component and terminating the cover crop later. If residue is building up, lower C:N ratio by increasing the legume and or brassicas and terminate earlier.

Full width soil tillage is not permitted for any crop.

The planned crop rotation including the cover crop and associated management activities will score a Soil Conditioning Index (SCI) value > 0, as determined using the current approved NRCS Soil Conditioning

Index (SCI) procedure, with appropriate adjustments for additions to and or subtractions from plant biomass.

The cover crop shall be planted as early as possible and be terminated as late as practical for the producer's cropping system to maximize plant biomass production, considering crop insurance criteria, the time needed to prepare the field for planting the next crop, and soil moisture depletion.

Additional Criteria Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Establish cover crops as soon as practical prior to or after harvest of the production crop. (i.e. before or after harvest)

Select cover crop species for their ability to effectively utilize nutrients.

Terminate the cover crop as late as practical to maximize plant biomass production and nutrient uptake. Practical considerations for termination date may include crop insurance criteria, the amount of time needed to prepare the field for planting the next crop, weather conditions, and cover crop effects on soil moisture and nutrient availability to the following crop.

If the cover crop will be harvested for feed (hay/balage/etc.), choose species that are suitable for the planned livestock, and capable of removing the excess nutrients present. When a cover crop will be grazed or hayed, ensure that crop selection(s) comply with pesticide label rotational crop restrictions and that the planned management will not compromise the selected conservation purpose(s).

Additional Criteria to Suppress Excessive Weed Pressures and Break Pest Cycles

Select cover crop species for their life cycles, growth habits, and other biological, chemical and or physical characteristics to provide one or more of the following:

- To suppress weeds, or compete with weeds.
- Break pest life cycles or suppress of plant pests or pathogens.
- Provide food or habitat for natural enemies of pests.
- Release compounds such as glucosinolates (brassicas) that suppress soil borne pathogens or pests.

Select cover crop species that do not harbor pests or diseases of subsequent crops in the rotation.

Additional Criteria to Improve Soil Moisture Use Efficiency

In areas of limited soil moisture, terminate growth of the cover crop sufficiently early to conserve soil moisture for the subsequent crop. Cover crops established for moisture conservation shall be left on the soil surface.

In areas of potential excess soil moisture, allow the cover crop to grow as long as possible to maximize soil moisture removal.

Additional Criteria to Minimize Soil Compaction

Select cover crop species that have the ability to root deeply and the capacity to penetrate or prevent compacted layers. A mixture of fibrous roots (e.g. grass) and tap roots (e.g. radish, turnip, clover) improve soil structure.

CONSIDERATIONS

Plant cover crops in a timely matter and when there is adequate moisture to establish a good stand.

When applicable, ensure cover crops are managed and are compatible with the client's crop insurance criteria.

Maintain an actively growing cover crop as late as feasible to maximize plant growth, allowing time to prepare the field for the next crop and to optimize soil moisture.

Select cover crops that are compatible with the production system, well adapted to the region's climate and soils, and resistant to prevalent pests, weeds, and diseases. Avoid cover crop species that harbor or carry over potentially damaging diseases or insects.

To improve fertility for the cover crop, phosphorus, potassium and lime can be applied to the cover crop for the following cash crop. Use Land Grant University's recommended nitrogen credits from the legume and reduce nitrogen applications to the subsequent crop accordingly. "Reduce N rate by 60 to 80 pounds per acre following a well-established single-species winter cover crop of crimson clover or hairy vetch that has reached early bloom stage." This will apply for all mixes that are 75% or more legume. For all others cover crop mixes, do not reduce N rate unless biomass is analyzed for N credit value.

Cover crops may be used to improve site conditions for establishment of perennial species.

When cover crops are used for grazing, select species that will have desired forage traits, be palatable to livestock, and not interfere with the production of the subsequent crop.

Use plant species that enhance forage opportunities for pollinators by using diverse legumes and other forbs.

Cover crops may be selected to provide food or habitat for natural enemies of production crop pests.

Cover crops residues should be left on the soil surface to maximize allelopathic (chemical) and mulching (physical) effects.

Seed a higher density cover crop stand to promote rapid canopy closure and greater weed suppression. Increased seeding rates (1.5 to 2 times normal) can improve weed-competitiveness.

Cover crops may be selected that release biofumigation compounds that inhibit soil-borne plant pests and pathogens.

Species can be selected to serve as trap crops to divert pests from production crops.

Select a mixture of two or more cover crop species from different plant families to achieve one or more of the following: (1) species mix with different maturity dates, (2) attract beneficial insects, (3) attract pollinators, (4) increase soil biological diversity, (5) serve as a trap crop for insect pests, or (6) provide food and cover for wildlife habitat management.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to achieve biological nitrogen fixation. Select cover crop species or mixture, and timing and method of termination that will maximize efficiency of nitrogen utilization by the following crop, considering soil type and conditions, season and weather conditions, cropping system, C:N ratio of the cover crop at termination, and anticipated nitrogen needs and residue cover for the subsequent crop.

Time the termination of cover crops to meet nutrient release goals. Termination at early vegetative stages may cause a more rapid release compared to termination at a more mature stage.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

Both residue decomposition rates and soil fertility can affect nutrient availability following termination of cover crops

Allelopathic effects to the subsequent crop should be evaluated when selecting the appropriate cover crop.

For nursery production, grass cover crops may be used as opposed to legumes since grass cover crops do not build up as much damping-off fungi as legume crops.

Do not plant high biomass cover on soils that are somewhat poorly drained or wetter, unless planting can be delayed allowing the cover crop to wick out moisture. High biomass cover can be planted when soil temperatures are optimum and soils are not wet. Good slot closure is important.

Do not harvest cover crops for seed other than that needed to seed the following year's cover crop.

CAUTION:
Brassicas are not recommended in a cover crop mix prior to cotton because of the sensitivity of the cotton seedlings.

Austrian winter peas can cause issues when planting cotton. A mid-morning soil temperature of 68°F at proper planting depth for three consecutive days and a favorable five-day forecast following the planting of cotton are best.

Slugs can be an issue in soybean fields when climatic conditions are cool, overcast and wet. When heavy residue is present, delay planting until growing conditions are good. Soybeans will germinate at 55 °F but ideal soil temperature is 77 °F.

Additional Considerations to Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Use deep-rooted species to maximize nutrient recovery.

When appropriate for the crop production system, mowing certain grass cover crops (e.g., sorghum-sudangrass, pearl millet) prior to heading and allowing the cover crop to regrow can enhance rooting depth and density, thereby increasing their subsoiling and nutrient-recycling efficacy.

Additional Considerations to Increase Soil Health and Organic Matter Content

Aerial seeding is a no-till planting method. Consider aerial seeding only during moist conditions when rain is forecasted.

Consider leaving brassicas out of the cover crop mix every other year.

For optimum soil health benefits, land managers are strongly encouraged to only graze the cover crops just prior to termination.

Rotating species in the cover crop mix can improve diversity.

Increase the diversity of cover crops (e.g., mixtures of several plant species) to promote a wider diversity of soil organisms, and thereby promote increased soil organic matter.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to provide nitrogen through biological nitrogen fixation.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for each field or treatment unit according to the planning criteria and operation and maintenance requirements of this standard. Specifications shall describe the requirements to apply the practice to achieve the intended purpose for the practice site. Plans for the establishment of cover crops shall, as a minimum, include the following specification components in an approved Cover Crop, 340, Implementation Requirements document:

- Field number and acres
- Species of plant(s) to be established.
- Seeding rates.
- Seeding dates.
- Establishment procedure.
- Rates, timing, and forms of nutrient application (if needed).
- Dates and method to terminate the cover crop.
- Other information pertinent to establishing and managing the cover crop e.g., if haying or grazing is planned specify the planned management for haying or grazing.

OPERATION AND MAINTENANCE

Evaluate the cover crop to determine if the cover crop is meeting the planned purpose(s). If the cover crop is not meeting the purpose(s) adjust the management, change the species of cover crop, or choose a different technology.

REFERENCES

A. Clark (ed.). 2007. Managing cover crops profitably. 3rd ed. Sustainable Agriculture Network Handbook Series; bk 9.

Hargrove, W.L., ed. Cover crops for clean water. SWCS, 1991.

Magdoff, F. and H. van Es. Cover Crops. 2000. p. 87-96 *In* Building soils for better crops. 2nd ed. Sustainable Agriculture Network Handbook Series; bk 4. National Agriculture Library. Beltsville, MD.

Reeves, D.W. 1994. Cover crops and erosion. p. 125-172 *In* J.L. Hatfield and B.A. Stewart (eds.) Crops Residue Management. CRC Press, Boca Raton, FL.

NRCS Cover Crop Termination Guidelines:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1077238

Revised Universal Soil Loss Equation Version 2 (RUSLE2) website:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/rusle2/

Wind Erosion Prediction System (WEPS) website:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/weps/

USDA, Natural Resources Conservation Service, National Agronomy Manual, 4th Edition, Feb. 2011. Website: http://directives.sc.egov.usda.gov/ Under Manuals and Title 190.

APPENDIX

Table 1: Recommended Cover Crop Mixes

COVER CROP EXAMPLE MIXES:				
Multiple Species Cover Crop Mix (Cool Season planted prior to Soybeans)				
Crop Mixes	**Seeding Rate Lb./Ac[1]**		**Seeding Date**	**C:N ratio in Late Vegetative State[5]**
	Drilled	**Broadcast**		
Mix 1				
Cereal Rye	20	26	August 15 to October 15	31
Oats[2]	20	26		
Austrian Winter Peas	11	14		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
or				
Mix 2				
Cereal Rye	20	26	August 15 to October 15	32
Wheat	15	20		
Crimson Clover	4	5		
Radish	1.5	1.5		
Hairy Vetch	4	5		
or				
Mix3				
Cereal Rye	28	36		35
Wheat	28	36		
Crimson Clover	4	5		
Radish	1	1		
Turnip	O.5	0.5		
Multiple Species Cover Crop Mix (Cool Season drilled only after double crop soybeans or cotton and up to 20% of land in full season soybeans.)				
Mix 4				
Cereal Rye	20	-	Drilled only up to November 1	33
Triticale	20	-		
Turnip	0.5	-		
Crimson Clover or Hairy Vetch	5	-		
Austrian Winter Peas[3]	13	-		
or				
Mix 5				
Black oats	20	-	Drilled only up to November 1	26
Barley	20	-		
Annual ryegrass[4]	10	-		
Crimson Clover or Hairy Vetch	5	-		
Turnip	0.5	-		
Basic Cover Crop Mix (Cool Season prior to Corn or Soybeans)				
Mix 6				
Cereal Rye	20	26	August 15 to October 15	30
Wheat	20	26		
Crimson Clover	5	7		
Austrian Winter Peas	14	18		
Radish	1	1		

Basic Cover Crop Mix (Cool Season prior to Corn)				
Mix 7				
Wheat	25	32	August 15 to October 15	25
Crimson Clover	5	7		
Austrian Winter Peas	14	18		
Hairy Vetch	5	7		
Radish	1	1		
Multiple Species Cover Crop Mix (Warm Season) Double crop soybean producers could plan a warm season cover crop to achieve 3 consecutive years of cover crops. This option is available to all producers.				
Mix 8				
Buckwheat (optional)	1	1	April 20 to July 1	21
Sunflowers (optional)	1	1		
Sudangrass	10	13		
Millet (any)	4	5		
Cowpeas	11	14		
Soybeans (optional)	11	14		
Turnips	1.5	1.5		
Sunhemp	5	7		
Multiple Species Cover Crop Mix (Self-Terminating) Must be approved by local District Conservationist.				
Mix 9				
Spring Oats	90	117	August 1 – Sept. 10	27
German Millet	20	26		
Spring Pea	15	20		
Radish	1.5	1.5		
Buckwheat	4	5		
Sunflower	2	3		

[1] If grazing is planned increase small grain seeding rate up to 100lb./ac.

[2] Black oats may be substituted for Winter Oats, although in the northern and high elevation areas black oats may freeze out in colder winters. Spring oats provide quick cover but may smother other species so rate should not be increased above 20 lb/ac.

[3] Austrian Winter Peas can be an issue to plant cotton into.

[4] Annual ryegrass, especially Italian ryegrass can be difficult to kill and if it goes to seed it could volunteer later. Best to use a variety with annual ryegrass to improve control of termination. Use a cold tolerant variety if planting late. Annual ryegrass is easier to control when it is terminated at 10". Only recommended for producers with experience controlling it. Not recommended if you plan to grow wheat in the future.

[5] The Carbon: Nitrogen (C:N) ratio is recommended to be 30:1 or higher prior to low residue crops and below 30:1 prior to high residue crops.

- All mixes are only examples of mixes that can be used. Other mixes can be approved for use.
- Buckwheat and sunflower at a 1 lb/ac rate can be added to any mix as long as it is 30 or more days till the date of the average killing frost. These would add to diversity but at this rate they would not count as one of the five species in a mix
- Seed needs to meet the state seed law. It can be variety not stated (VNS), a Variety, certified seed or seed harvested from the producer's farm. Ideal is to be a Variety due to uniformity, Branded seed can be VNS seed.
- Seeding rate can be increased on all species but be aware that early production species can shade and reduce the stand of slower growing species. E.g. radish and or turnip could reduce the stand of other species.
- Some producers have reported a corn yield drag after cereal rye. If it is a concern other small grains can be substituted. Most likely the issue is too much carbon in mixture causing a higher C:N ratio.
- Recommend not using brassicas preceding cotton and caution using Austrian winter peas prior to cotton.
- Brassicas are heavy feeders and caution needs to be taken when using them. Maintain good fertility for the following crop.
- Mixes can be developed using the "smart mix 5_20_17 KB slim version.xlsx" calculator. No more than 1.5 lb. of brassicas is typically recommended in a mixture. Turnip and more so rape (canola) can be difficult to kill.
- Mixes can be developed using the "smart mix 5_20_17 KB slim version.xlsx" calculator. No more than 1.5 lb. of brassicas is typically recommended in a mixture. Turnip and more so rape (canola) can be difficult to kill.

- Cover crop species that have worked well in suppressing herbicide resistant weeds such as palmer amaranth and horseweed (marestail) are cereal rye, annual ryegrass, rape and black oats. Sorghums, warm season annuals are also reported to have some allelopathic nature.
- Legumes are typically coated and pre-inoculated if not order fresh inoculant and inoculate seed at seeding.

Full Rates of Single Species (not a complete list)					
Plant Species	Peak Bloom Period	Seeding Rate lb./Ac		Seeding Date	Note
		Drilled	Broadcast		
Barley (CSA)	May	90	112	Aug. 15 to Nov. 1	Can be planted later than most cereals
Buckwheat (WSA)	21 days after planting	35	42	June 1 to Aug. 15	Quick warm season cover, can be added as 1 lb/ac to any mix between the last frost and 30 days prior to the first frost
Clover, Crimson (CSA) (ss)	Late April or May	17	21	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Tap root, late spring growth
Clover, Berseem (CSA) (ss)	June	11	14	Feb. 20 to Ap. 1	
Clover, Red (CSP) (ss)	July	8	10	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	
Cowpea	July	56	70	May 20 to June 20	High N producer
Millet, Browntop (WSA)	August	17	21	May 1 to July 1	Quick cover
Oats (CSA)	May	100	140	Sept. 1 to Oct. 1 Feb. 20 to Ap. 1	Spring oats can give quick cover in the fall but will winter kill and may smother other species. Black oats, not as cold tolerant as winter oats but may help weed control.
Phacelia	6 wks. after germ.	15	20	May 1 to June20	Good for beneficial organisms
Radish, forage (CSA)	-	8	10	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	May freeze out. 1.5 lb/ac is enough in a mix
Rye, cereal (CSA)	May	90	112	Aug. 15 to Nov. 1	Highest biomass, most cold tolerant, may increase weed control. Tolerant of somewhat poorly drained soils
Ryegrass, annual	June	20	30	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Can be invasive particularly in wheat. Deep rooted and tolerant of poorly drained soils
Sudangrass (WSA)	July	28	35	May 1 to June20	Deep strong roots, can help in weed control
Sunflower (WSA)	July-Aug.	9	11	April 15 to May 15	Can be added as 1 lb/ac in a mix as late as 40 days prior to first frost
Sunhemp (WSA)	-	20	25	May 1 to July 20	Need 60 days minimum growth, N producer
Sweet clover (CSB)	July	13	17	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Could be added as 1 lb/ac in a mix
Turnips (CSA)	-	3	4	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	No more than 1.5 lb/ac in a mix
Vetch, hairy (CSA)	May	22	28	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Can be invasive particularly in wheat, tolerant of low fertility and somewhat poorly drained soils
Wheat (CSA)	June	90	112	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Low cost, reduced vigor following sorghums
Winter Peas, Austrian	May	40	50	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Somewhat slow to establish, produce a lot of biomass in spring

Note: CSA = Cool Season Annual, CSP= Cool Season Perennial, WSA= Warm Season Annual, ss = subsoiler crop or tap rooted, Ideal seeding depth is 8x the width of the seed. Typically in mixed species seeding depth should be 0.50” to 0.75”.

COVER CROP (340) REQUIREMENTS IN TENNESSEE

2017 Environmental Quality Incentives Program (EQIP)

Purpose: To improve soil health function by controlling erosion, building organic matter, increasing available water holding capacity, and promoting nutrient retention and recycling.

Objective: To continue the growth of the cover crops for the production of biomass above and below the ground for as long as possible before the following crop is planted. Producers are encouraged to plant early maturing crops and cover crops.

Eligible Land: Cropland where annual crops are grown.

Soil Testing: Using the Soil Health Test (Haney test) is recommended for selecting the best cover crop mixes to increase soil biology. Results can also be used to determine when fertilizer inputs can be reduced. Soil samples taken at the same time (either fall or spring) and location will best document soil health trends over time. If historic yields, management and soils are similar acreage up to 50 total acres can be sampled as one.

Planting Requirements (for all cover crops):

- Cover crops and the following crop will be planted no-till. Exception: crops that have not been traditionally planted no-till (ONLY tobacco, green beans and vegetable crops) may be strip tilled at planting when meeting a STIR value $\leq$20 for each crop in the rotation. Full width tillage is not permitted for any crop. Consider using a crop roller when planting. **NOTE:** Aerial seeding is a no-till method (aerial seeding during moist conditions with follow up rain is best).
- Currently tilled cropland can convert to a no-till residue management system.
- Planting dates are to be strictly adhered to and producer is locked into a planned crop rotation.
- Cover crops are **not** to be managed as a harvested crop. P and K can be applied to cover crop for the crop following the cover crop.

Termination Requirements (for all cover crops):

- In order to benefit from nitrogen fixation by legume cover crops, allow legumes to reach early to mid-bloom stage prior to being killed.
- For pollinator crops, allow plants to reach full bloom.
- **Do not allow cover crop to go to seed,** however, in mixed species stands allowing some species to go to seed is acceptable, but realize the potential impacts on future wheat crops.
- Cover crops will serve as cover for a **minimum of 90 days.**
- At termination, the cover crop should have 90% or better ground cover and a **minimum height of 10 inches**.
- Terminate cover crops 7 to 14 days prior to planting to reduce allelopathic (toxic) activity toward the primary crop. Sorghum and cereal rye are plants that have strong allelopathic activity which may be beneficial for weed control. Typically terminate with Glyphosate at bloom stage or early head stage wait 14 days and spray gramoxone. If brassicas are in the mix spray broadleaf spray 2,4-D or Banvel 30 to 45 days prior to planting broadleaf crops like cotton, soybeans and tobacco. Always follow directions on the label and/or Univ. of TN herbicide recommendations.
  https://extension.tennessee.edu/publications/Documents/PB1580.pdf

Grazing Cover Crop Requirements:

- Only producers with a commitment to manage grazing heights are allowed to graze cover crops.
- Management technique will be to take half-leave half; allowing cover to reach 8" height then graze to 4" minimum height, maintaining 70% ground cover. To realize optimum benefits producers are strongly encouraged to only graze the cover crops just prior to termination.
- Producer must have an area to remove livestock from the cover crop when the cover crop is vulnerable to overgrazing or excessive trampling.
- Cover crop can be grazed to a 4" minimum height prior to termination.
- No mechanical harvest (e.g. silage, balage, hay etc.) allowed.
- Base sacrifice area on feeding site assessment tool. Sacrifice area will not receive payment.

Leave an untreated area (for all cover crops):

- For all cover crops, leave a portion of the field or similar field to compare results.
- Area should be wide and large enough to get a reliable yield monitor reading.
- Only planted cover crop acres will receive payment.

Planting Options (for all cover crops):

- When planting with a drill use the lower recommended seeding rate. For broadcast (aerial) seeding, seed a minimum of 1.3 times the low rate.
- In developing mixes, seed a minimum of 70% of legume full rate in Nitrogen fixing cover or develop mix based on C: N ratio.
- Total seeding rate will equal 100% or higher. Up to 20% of mix can be a species that will be terminated by frost or heat (e.g. buckwheat with cool season mix planted in August.)
- 10% or more of the recommended full rate is required to count as a species in the 5 species mix, no more than 1.5 lb of total brassicas are recommended in a mix. If planting after Oct. 1 don't plant radish in the mix.

Select Cover Crop: Small grain and legume will make up 10% or more of the full seeding rate in the mix, brassica 5% to 15% (0.5 to 1.5 lb) of the full seeding rate in the mix. Consider leaving brassicas out of the cover crop every other year.

- **Basic (up to 3 yr):** Five species minimum (e.g. Rye, oats, wheat, radish, and turnips). Target the C:N ratio to be 24:1 but less than 31:1.
- **Multiple Species (3 yr):** (small grain, legume and brassica mix 5 species minimum): see planting options.
    - Target C:N ratio prior to a high residue crop to be 30:1 or less.
    - Target C:N ratio prior to a low residue crop to be 31:1 or higher.

C:N Ratio: The C:N ratio effects residue cover and nutrient cycling. For early soil health conditions (beginning stages), the target C:N ratio is 24-30:1. After soil health is more developed, the target C:N ratio will increase to 31-50:1. Look at the soil surface, if the residue is lacking increase the C:N ratio by increasing the grass component and terminating the cover crop later. If residue is building up on the soil surface, decrease the C:N ratio of the cover crop.

Cover Crop Example Mixes

Crop Mixtures	Seeding Rate Seeding lb/ac Drilled	Broadcast (Option: If grazing is planned increase small grain seeding rate up to 100 lb/ac)		C:N rate at Vegetative Stage
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	20	26	Aug. 15 to Oct. 15	31
Oats	20	26		
Austrian W	11	14		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	20	26	Aug. 15 to Oct. 15	32
Wheat	15	20		
Crimson Clover	4	5		
Radish	1.5	1.5		
Hairy Vetch	4	5		
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	28	36	Aug. 15 to Oct. 15	35
Wheat	28	36		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
Multiple Species Cover Crop Mix (Cool Season drilled only after double crop soybeans or cotton and up to 20% of land in full season soybeans can be drilled till Nov. 1 in this mix).				
Cereal Rye	20		Drilled only, up to Nov. 1	33
Triticale	20			
Turnip	0.5			
Crimson clover or hairy vetch	5			
Austrian winter peas	13			
Multiple Species Cover Crop Mix (Warm Season) Double crop soybean producers could plant a warm season cover crop to achieve 3 consecutive years of cover crops. This option is available for all producers.				
Buckwheat (optional)	1	1	April 20 to July 1	21
Sunflowers (optional)	1	1		
Sudangrass	10	13		
Millet	4	5		
Cowpeas	11	14		
Soybeans	11	14		
Turnips	1.5	1.5		
Sunhemp	5	7		

Basic Cover Crop Mix 1				
Cereal Rye	20	26	Aug. 15 to Oct. 15	30
Wheat	20	26		
Crimson Clover	5	7		
Austrian Winter Pea	14	18		
Radish	1	1		
Basic Cover Crop Mix 2				
Wheat	25	32	Aug. 15 to Oct. 15	25
Crimson Clover	5	7		
Austrian Winter Pea	14	18		
Hairy Vetch	5	7		
Radish	1	1		

- All mixes are only examples of mixes that can be used. Other mixes can be approved for use.
- Seed needs to meet the state seed law. It can be variety not stated (VNS) or certified seed or seed harvested from producer's farm.
- Seeding rate can be increased on all species but be aware that early production species can shade and reduce the stand of slower growing species. E.g. radish or turnips could reduce the stand of other species.
- Some producers have reported a corn yield drag after cereal rye. If it is a concern, other small grains can be substituted. Most likely the issue is too much carbon in mixture causing a higher C:N ratio.
- Recommend not use brassicas preceding cotton.
- Brassicas are heavy feeders and caution needs to be taken when using them. Maintain good fertility for the following crop.
- Mixes can be developed using the Green Cover Seed Smart mix calculator. No more than 1 ½ lbs of brassicas is typically recommended in a mixture. Turnips and more so rape (canola) can be difficult to kill. http://www.greencoverseed.com/smartmix_web/smartmix_web.htm
- High biomass cover crops, like cereal rye, have worked best in control of palmer amaranth.
- Annual Ryegrass has allelopathic (toxic) nature too but is only recommended for those who have experience using it. Annual ryegrass especially Italian ryegrass can be hard to kill and become a weed.
- Sorghums are warm season annuals with some reported allelopathic nature.
- Buckwheat is a succulent fast growing annual that winter kills very easy; it or other warm season cover crop species can make up 20% of the mix. Buckwheat is a very good attractant of beneficial insects.
- Legumes are typically coated and pre-inoculated if not order fresh inoculant and inoculate seed at seeding.

Producer	District Conservationist

Additional seeding options (full rates listed)				
Plant Species	**Peak Bloom Period**	**Seeding Rate Lb/Ac** **Drilled** **Broadcast**	**Seeding Date**	**Note**
Buckwheat (WSA)	21 day after planting	35 42 1 lb/ac for mix	June 1 to Aug 15	Quick warm season cover, can be added as a minor component of fall cool season mix
Clover, crimson (CSA) (ss)	May	17 21	Aug 15 to Oct 15 Feb 20 to April 1	Tap root, late spring growth
Clover, berseem (CSA) (ss)	June	11 14	Feb 20 to April 1	Tap root
Clover, red (CSP) (ss)	July	8 10	Aug 15 to Oct 15 Feb 20 to April 1	Tap root
Cowpea (WSA) (ss)	July	56 70	May 20 to June 20	Tap root, High N producer
Millet, Browntop (WSA)	August	17 21	May 1 to July 1	Quick cover
Oats (CSA)	May	100 140	Sept 1 to Oct 1 Feb 20 to April 1	May freeze out
Radish, forage (CSA) (ss)	-	8 10 No more than 1.5 lb/ac of brassicas	Aug 15 to Oct 15 best sown before Sept 15 Feb 20 to April 1	may freeze out at 25 degrees F, tap root, 1.5 lb/ac is enough
Rye, cereal (CSA)	May	90 112	Aug 15 to Nov 20	Allelopathic to palmer amaranth, plant small seeded crops 2 wk after rye termination
Sudangrass (WSA) (ss)	July	28 35	May 1 to June 20	Strong roots
Sunflower (WSA)	July - Aug	9 11 1 lb/ac for mix	April 15 to May 15	Fast establishment
Sun hemp, (WSA) Tropical (ss)	-	20 25	May 1 to July 20	Need 60 days minimum growth high biomass and N producer
Sweet clover (CS Biennial) (ss)	July	13 17	Aug 15 to Oct 15 Feb 20 to April 1	Allelopathic to thistle and green foxtail, 1 lb/ac
Turnips (CSA) (ss)	-	3 4 No more than 1.5 lb/ac of brassicas	Aug 15 to Oct 15 Feb 20 to April 1	Very small seed (electric seeder or carrier like pelletized lime or crimson clover, 1.5 lb/ac
Vetch, hairy (CSA) (ss)	May	22 28	Aug 15 to Oct 15 Feb 20 to April 1	Can be invasive, late spring growth, tolerant of low fertility, High N producer
Wheat (CSA)	June	90 112	Sept 15 to Nov 10 Feb 20 to April 1	Low cost quick cover, reduced vigor following sorghums
Winter Peas, Austrian (CSA)(ss)	May	40 50	Aug 15 to Oct 15 Feb 20 to April 1	Slow to establish

Note: CSA = Cool Season Annual, CSP = Cool Season Perennial, WSA = Warm Season Annual, WSB = Warm Season Biennial, ss = subsoiler crop

USDA
United States Department of Agriculture

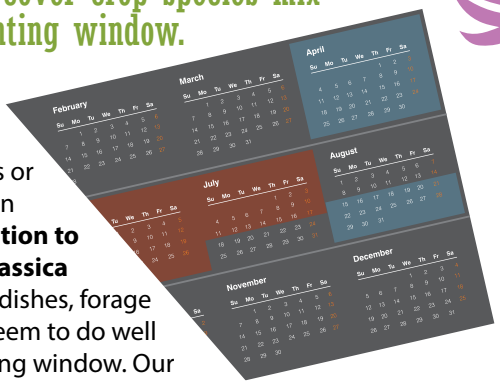
Cover Crop Tips

Natural Resources Conservation Service
Montana

1 Let your goals and resource concerns guide your cover crop design.

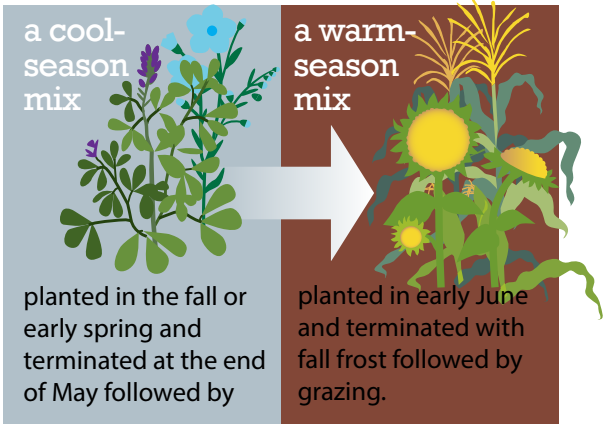
For example, a cover crop designed for grazing should be different than a cover crop designed for maximum nitrogen fixation. Plan accordingly.

2 Tailor the cover crop species mix to the planting window.



Mixes are most successful when they are mostly cool-season species or mostly warm-season species. **One exception to this may be the brassica species.** Turnips, radishes, forage kale, and collards seem to do well regardless of planting window. Our cool-season planting window is usually April to mid-May and mid-August to early September. Our warm-season window is mid- May to mid-June (shallow soil temps 70 degrees F or warmer and adequate soil moisture). Planting cool and warm season species in mixes together is generally not recommended unless a mid-season planting date is used when chance of frost is over. Some areas may not have a warm season due to high elevation and/or short growing season.

3 If you want cover over an entire growing season, you may need to plant two cover crops:



4 The overall crop rotation is more important than a single cover crop for adding diversity.

Use the cover crop to fill gaps in the rotation. A cover crop mix does not need to have all four plant functional groups (cool-season broadleaf, cool-season grass, warm-season broadleaf, warm-season grass) to be successful.

5 Plan for adequate weed control,

especially prior to seeding a mixed cover crop. Allow time for a flush of weeds and adequate weed kill prior to seeding. Once the cover crop is planted, few weed control strategies are available if something gets out of control.

6 Likewise, certain cover crop species can become weeds the following year if allowed to go to seed.

Consider crops in the entire rotation and ensure cover crop species will not become a weed or carry diseases that could jeopardize cash crops. For example, buckwheat should not be planted within two calendar years of planting a commercial wheat crop due to severe allergy problems in the Japanese population, where much of Montana's wheat is exported. Termination before seed-set is also important.

7 More cover crop species are not always better than fewer

species for biomass production. There seems to be a biomass threshold for each site, and the addition of more species may only dilute the effects of the strongest competitors.

there's more

Cover Crop Tips

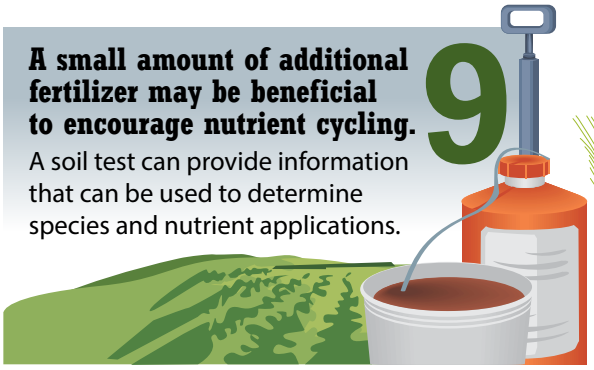
Natural Resources Conservation Service Montana

8 

Even in small amounts, certain cover crop species can provide flowers that are beneficial to pollinators and beneficial insects.

9 **A small amount of additional fertilizer may be beneficial to encourage nutrient cycling.**

A soil test can provide information that can be used to determine species and nutrient applications.



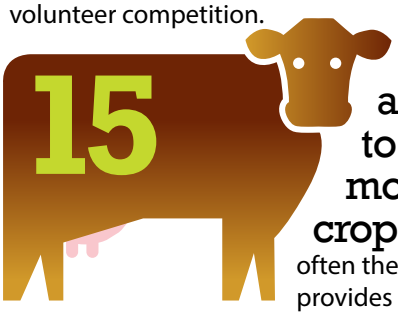
10 **Soil moisture conservation is critical for dryland cover crops.** Be mindful that our peak precipitation window is April through early June, with a very dry period from June 15th onward. In dryland situations where soil moisture is critical, plan a cool-season cover crop to be planted in late fall or early spring and terminated by June 15th. Be particularly mindful of this in annual precipitation zones of 13 inches or less.

11 **Using cover crops in dryland prior to winter wheat seeding may be one of our most challenging cover crop scenarios,** as there is no time for soil moisture recharge prior to wheat seeding. In addition, the threats of diseases such as rhizoctonia or wheat streak mosaic virus needs to be addressed by breaking the "green bridge." Breaking the "green bridge" means having a period of several weeks prior to seeding with no growing plants. For a partial fallow replacement in a winter-wheat rotation, plant a spring-seeded, cool-season cover crop and terminate based on soil moisture, weeds and cover crop maturity. When considering a warm-season cover crop for fallow replacement, it may be best to follow the cover crop with a spring-seeded cash crop.

12 **Be aware** that the Risk Management Agency (RMA) requires 35 days of no crop growth between cover crop termination and winter wheat seeding for crop insurance purposes. If a crop, or a cover crop, is planted on summerfallow acreage in a fallow year, the following planted crop will not meet the RMA Summerfallow Practice definition until the acres lie fallow for a full crop year. However, the acreage may be insured under the "Continuous Cropping Practice". Check with your crop insurance agent or RMA before planting cover crops to understand the implications on crop insurance.

13 **When cover crops follow small grains** especially barley, under irrigated or high moisture conditions spray after small grain harvest to decrease volunteer competition.

14 **Annual cover crops are only one tool to build soil health.** Perennial crops and diverse rotations also provide positive soil health benefits.

15 

Grazing can be an excellent way to re-coup the money in a cover crop investment. Fall is often the best time for grazing, as it provides supplemental forage at a necessary time of the year, and the combination of frost and grazing makes it easy to terminate the crop. Ensure species planted are not poisonous to livestock and send forage samples to a certified lab for nitrate and other toxicity tests as needed, and a forage quality analysis prior to grazing.

16 **Improving soil health is a long-term commitment.**

It can take 10 to 15 years to noticeably build soil organic matter in dryland crop systems. Be patient.

17 **Cover crops require good management.**

Growers new to the technique are advised to **start small** (5 –10 acres) and build on lessons learned.

MT 03/16

10. Earthworms

Earthworms are most active during the spring and fall, which are the best times to observe their activity.

Materials needed to measure the number of earthworms:

- **tap water (2 L)**
- **hand trowel or shovel**
- **large jar or container for worm collection and cleaning**
- **mustard solution (2 tablespoons mustard powder in 2 liters of tap water)**

Did You Know?
Earthworm burrowing improves infiltration and their casts improve aggregation. Earthworms also break down larger bits of residue for use by other soil organisms.

Considerations: When examining the soil for earthworms, avoid places where their populations might be affected, such as near mulch or compost piles. The abundance of earthworms is usually patchy within a field and varies with season. Therefore, count earthworms several times during a season and use the average to gauge changes from year to year.

1 **Dig Plot**

Measure a square-foot plot and dig down 12 inches with the hand trowel or shovel (**Figure 10.1**). Try to minimize the number of cuts with the shovel to avoid damage to the earthworms. **Dig the hole first, then sort for earthworms.**

Figure 10.1

2 **Count the Number of Earthworms**

Sort the soil samples against a pale-colored background to help locate the earthworms. Separate and count the number of earthworms.

3 **Add Mustard Solution (optional)**

To facilitate extraction of deep burrowing earthworms, add two liters of mustard solution to the hole. **First**, make sure the bottom of the hole is level. The deep burrowing worms should appear within five minutes (**Figure 10.2**). Count the number of worms.

Figure 10.2

4 **Record Total Number of Earthworms**

Record the total number of earthworms (those found in the hole and after adding the mustard solution) on the Soil Data worksheet. **[The mustard solution should not harm the worms. Rinse them in water before returning them to the soil.]**

5. Electrical Conductivity Test

Soil samples for the electrical conductivity (EC) test are taken from the 0- to 3-inch depth. Bulked soil samples from across the field can be collected, and two subsamples can be taken for analysis (See Chapter 1, Sampling Guidelines). **Electrical conductivity, pH, and soil nitrate are all measured from the same soil subsample.**

Materials needed to measure electrical conductivity (EC):

- **1/8-cup (30 mL) measuring scoop**
- **120-mL plastic containers with lid**
- **EC pocket meter (blue with black cap)**
- **squirt bottle**
- **calibration solution (0.01 M KCl)**
- **distilled water**

Did You Know?
Excess salts in soil can be a detriment to plant health. Salts can also hamper water movement into the soil and increase the occurrence of surface compaction.

1 Extract Subsample

The soil sample should be thoroughly mixed before taking a subsample. Measure a 1/8-cup level scoop subsample of soil and place it in the plastic container. If soil nitrates will be measured on this subsample (Chapter 7), weigh the subsample for a more accurate estimate of soil nitrates. Enter the subsample weight on the Soil Data worksheet.

2 Add Water to Subsample and Mix

- Add 1/8-cup (30 mL) of distilled water to the container with the subsample. The resulting soil/water mixture equates to a 1:1 soil to water ratio on a volume basis.
- Put the lid on the container and shake vigorously about 25 times.

Calibration Tip: Make sure the EC meter is calibrated before making a measurement. See Appendix C for calibration instructions.

3 Measure and Record EC (See Calibration Tip)

- Open the container and insert the EC pocket meter into the soil-water mixture. Take the reading while the soil particles are still suspended in solution. To keep the soil particles from settling, stir gently with the EC pocket meter. Do not immerse the meter above the immersion level (See Appendix C, Figure 1c). Allow the reading to stabilize (stays the same for about 10 seconds).
- Enter the EC reading on the Soil Data worksheet in decisiemens per meter (dS/m). The DiST WP 4 meter gives readings directly in dS/m. For the Microsensor 4 meter, divide the reading by 10, and for the Microsensor 3 meter, divide the reading by 100 to get readings in dS/m.
- Save the soil-water mixture for the pH measurement (Chapter 6).

4 Turn the meter off. Thoroughly rinse meter with distilled water and replace cap.

3. Infiltration Test

The infiltration test is generally performed after the **first** respiration measurement. The same 6-inch diameter ring left in place from the soil respiration test can be used for the infiltration test. If soil respiration was not determined, follow the instructions in Step 1 of the soil respiration procedure (Chapter 2) for inserting the 6-inch diameter ring.

Materials needed to measure infiltration:

- **6-inch diameter ring (left in soil from respiration test)**
- **plastic wrap**
- **500 mL plastic bottle or graduated cylinder**
- **distilled water**
- **stopwatch or timer**

Did You Know?

Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface runoff on sloping fields.

Considerations: If the soil is saturated, infiltration will not occur. Wait for one or two days to allow for some drying. Also, if the respiration test is not performed, make sure the sampling area is free of residue and weeds or that vegetation is trimmed to the soil surface before inserting the ring.

1 **Firm Soil**

With the 6-inch diameter ring in place, use your finger to gently firm the soil surface **only** around the **inside edges** of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil surface inside the ring.

2 **Line Ring with Plastic Wrap**

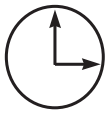
Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring as shown in **Figure 3.1.** This procedure prevents disturbance to the soil surface when adding water.

Figure 3.1

3 **Add Water**

- Fill the plastic bottle or graduated cylinder to the 444 mL mark with distilled water.
- Pour the 444 mL of water (1" of water) into the ring lined with plastic wrap as shown in **Figure 3.1.**

4 Remove Wrap and Record Time



- Remove the plastic wrap by gently pulling it out, leaving the water in the ring **(Figure 3.2)**. N**ote the time.**

- Record the amount of time (in minutes) it takes for the 1" of water to infiltrate the soil. Stop timing when the surface is just glistening.

Figure 3.2

- If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening **(Figure 3.3)**.

- Enter the amount of time in minutes on the Soil Data worksheet.

Figure 3.3

5 Repeat Infiltration Test

In the same ring, perform Steps 2, 3, & 4 with a second inch of water. On the Soil Data worksheet, enter the number of minutes elapsed for the second infiltration measurement. If soil moisture is at or near field capacity, the second test is not necessary.

[The moisture content of the soil will affect the rate of infiltration; therefore, two infiltration tests are usually performed (if soil is dry). The first inch of water wets the soil, and the second inch gives a better estimate of the infiltration rate of the soil.]

6 Replace Lid

If a second respiration measurement will be performed, set the lid loosely on the ring and leave it covered for preferably 16 to 24 hours (6-hour minimum) before beginning the second test (Chapter 2). (Remove lid and replace it before beginning the second soil respiration measurement).

> **!** **Reminder**: If you still need to perform the second respiration measurement, remember to loosely place the lid back on the ring before leaving the field.

6. Soil pH Test

Use the same soil-water mixture prepared in the EC test to conduct the pH Test. **If you are starting with a fresh soil sample, read the introduction and follow Steps 1-3 in the EC Test Chapter on preparing the sample.**

Materials needed to measure pH:

- **1/8-cup (30 mL) measuring scoop**
- **plastic specimen bottle**
- **calibration buffer solutions**
- **squirt bottle**
- **pH pocket meter (red with black cap)**
- **distilled water**

Did You Know?
Soil acidification can also be an indication of excessive N fertilizer applications and N leaching loss.

Considerations: If the soil sample is saturated or very wet, a 1:1 ratio, on a volume basis, of soil to water will not be obtained in the soil-water mixture (See Step 2, Chapter 5). Let the soil dry before proceeding with Step 1 in Chapter 5. Also, a small amount of salts diffuse out of the pocket pH meter; therefore, **EC measurements should always be taken first when measuring both EC and pH on the same sample**.

① Measure and Record pH

- Make sure to periodically calibrate your pH meter (See Appendix C for instructions). If the meter has not been used in a while, place the meter in tap water for about 5 minutes before calibrating or taking a reading.

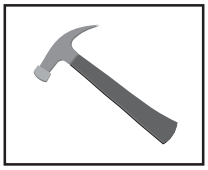
- Wait about 10 to 15 minutes after the EC measurement before measuring the pH. This gives the soil particles time to settle. Insert the pH pocket meter into the topmost portion of the solution and turn the meter on. Wait until the reading stabilizes (0-30 seconds), and record the digital reading on the Soil Data worksheet.

② Rinse Pocket Meter

- Thoroughly rinse the electrode with distilled water.

- Store the electrode with a few drops of the **pH 7** buffer solution and replace the cap. (See Appendix C on storage of pH meter)

Maintenance Tips: Check the batteries and calibrate the EC and pH meters periodically. Be sure to clean the meters thoroughly to keep them working properly.



11. Soil Physical Observations and Estimations

Materials needed in observing the soil physical properties:

- **tape measure**
- **sharpshooter spade or shovel**
- **18-inch metal rod**
- **tap water**

1 **Dig hole**

Dig a hole to a depth of 1 foot. Make it wide enough to cut out a slice of soil.

2 **Cut Slice of Soil**

Using the shovel, cut a slice of soil from a wall of the hole and lay it on the ground.

Figure 11.1

3 **Measure Depth of Topsoil**

- Measure the depth of the topsoil. Look for color changes from the soil surface downward through the soil profile. The topsoil is usually distinguished by a darker color than the underlying material **(See Figure 11.1)**.

- Record the depth of topsoil on the Soil Data worksheet.

4 **Observe Plant Roots**

- Observe plant roots in the hole and the slice of soil. To get a better look at the roots, dig down along a plant stem. The roots should be well branched with lots of fine root hairs.

- Things to look for are balled up roots or roots growing sideways. A lack of fine root hairs indicates oxygen deprivation in the root zone. Lateral root growth indicates a hardpan, or compacted layer.

5 **Determine Resistance**

- Use the metal rod to probe one of the side walls, starting from the soil surface to the bottom of the hole. Determine changes or differences in penetration resistance as you probe the side wall **(See Figure 11.2)**.

- Look for compacted layers that may restrict root growth and water movement.

Figure 11.2

6 Examine Soil Structure

Observe soil structure in the slice of soil to a depth of about 12 inches. Measure and mark, starting at the surface and moving downward; depth increments of 0 to 4 inches, 4 to 8 inches, and 8 to 12 inches. Note and record the type, size, and grade of the soil structural units or aggregates for each depth increment.

Note: Soil structure is how particles of soil are grouped together in stable collections or aggregates.

6a Note the type of soil structure at each of the three depth increments.

- The three general types of soil structure are granular (**Figure 11.3**), blocky (**Figure 11.4**), and platy (**Figure 11.5**).

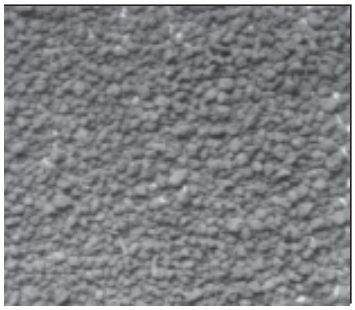


Figure 11.3 Granular: imperfect spheres, usually sand-size.

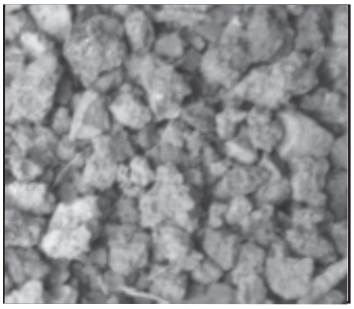


Figure 11.4 Blocky: imperfect cubes with angular or rounded edges.

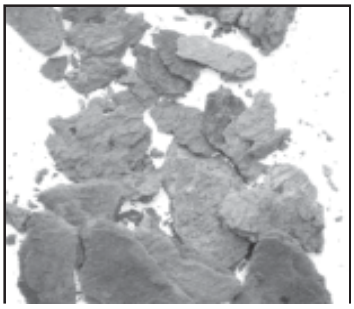


Figure 11.5 Platy: a flattened or compressed appearance.

- If there are no noticeable aggregates or peds, the soil has no structure. It is either single grained (**Figure 11.6**) or massive (**Figure 11.7**).

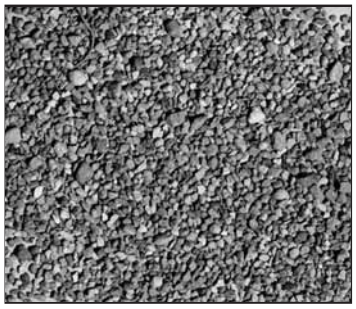


Figure 11.6 Single grain: unconsolidated mass such as loose sand.

Figure 11.7 Massive: cohesive mass.

- Record on the Soil Data worksheet the type of structure observed for each depth increment.

6b **Note the size of the aggregates or peds at the different depths**.

- Estimate the general size of the aggregates or peds. If the structure is granular, choose from fine (**Figure 11.8**), medium (**Figure 11.9**) and coarse (**Figure 11.10**) granule sizes.

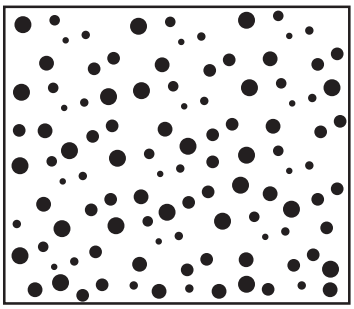


Figure 11.8
Fine: < 2 mm.

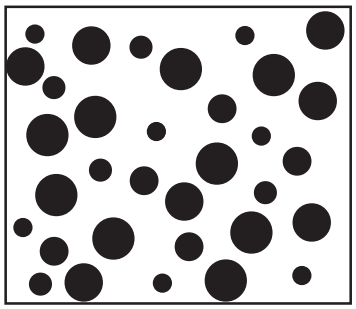


Figure 11.9
Medium: 2 to 5 mm.

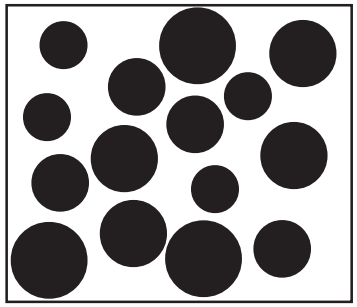


Figure 11.10
Coarse: 5 to 10 mm.

- If the structure is blocky, choose from very fine (**Figure 11.11**), fine (**Figure 11.12**), and medium (**Figure 11.13**) block sizes.

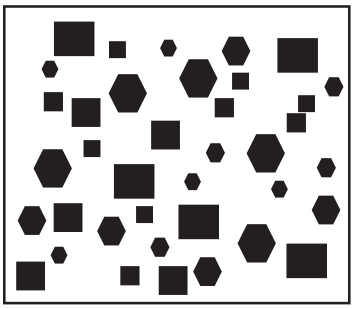


Figure 11.11
Very fine: < 5 mm.

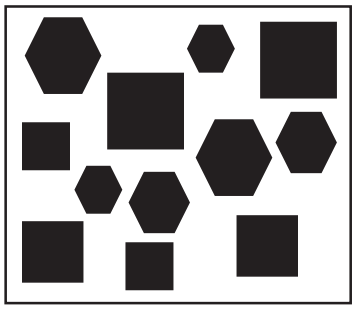


Figure 11.12
Fine: 5 to 10 mm.

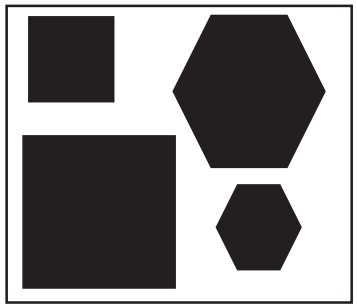


Figure 11.13
Medium: 10 to 20 mm.

- If structure is platy, choose from thin (**Figure 11.14**), medium (**Figure 11.15**), and thick (**Figure 11.16**) plate sizes.

Figure 11.14
Thin: < 2 mm.

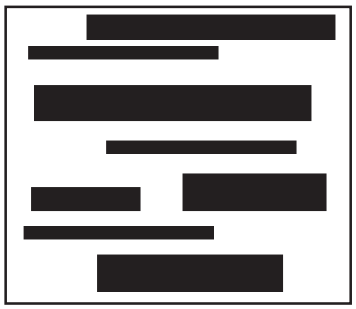


Figure 11.15
Medium: 2 to 5 mm.

Figure 11.16
Thick: 5 to 10 mm.

- Record on the Soil Data worksheet the size of the aggregates or peds observed for each depth increment.

6c **Note the distinctness (grade) of the aggregates in place and when removed from the slice of soil.**

The distinctness of the aggregates is either weak, moderate, or strong.

Weak structure:

- Aggregates or peds are barely observable in place in moist soil.
- When removed, the structure breaks into a few observable aggregates or peds **(Figure 11.17)**.

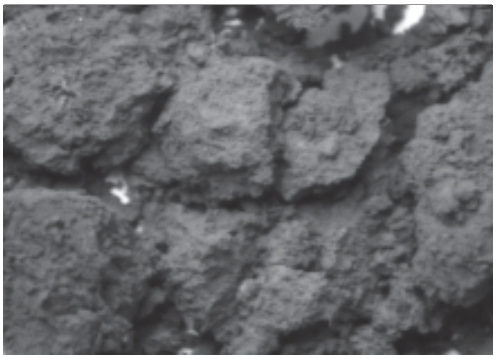


Figure 11.17

Moderate structure:

- Aggregates or peds are moderately well-formed and distinct in place.
- When removed, many well-formed aggregates are observable **(Figure 11.18)**.

Figure 11.18

Strong structure:

- Aggregates or peds are well-formed and very evident in place.
- When disturbed, the structure breaks into quite evident aggregates or peds **(Figure 11.19)**.

Record on the Soil Data worksheet the grade of the aggregates or peds observed for each depth increment.

Figure 11.19

7 **Determine soil textural class**

- Perform the Texture by Feel procedure **(See page 27)** on the top three inches of soil.
- Record on the Soil Data worksheet the soil textural class.

TEXTURE BY FEEL PROCEDURE

Making a Ribbon

Place approximately 25 grams in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.

Add dry soil to soak up water

Yes

Yes

Does soil remain in a ball when squeezed?

No

Is the soil too dry?

No

Is the soil too wet?

No

Sand

Yes

Place ball of soil between thumb and forefinger, gently push the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.

Does the soil form a ribbon?

No

Loamy Sand

Yes

Does soil make a weak ribbon less than 1 inch long before breaking?

No

Does soil make a ribbon 1 inch long before breaking?

No

Does soil make a strong ribbon two inches or longer before breaking?

Yes

Yes

Yes

Excessively wet a small pinch of soil in palm and rub with forefinger.

Sandy Loam

Yes

Does soil feel very gritty?

No

Silt Loam

Yes

Does soil feel very smooth?

No

Loam

Yes

Neither gritty nor smooth?

Sandy Clay Loam

Yes

Does soil feel very gritty?

No

Silty Clay Loam

Yes

Does soil feel very smooth?

No

Clay Loam

Yes

Neither gritty nor smooth?

Sandy Clay

Yes

Does soil feel very gritty?

No

Silty Clay

Yes

Does soil feel very smooth?

No

Clay

Yes

Neither gritty nor smooth?

Recommendations

- Evaluate soil health periodically (about every 3 years) to document changes.
- Consider looking at the soil health in the fence row relative to the field
- Periodic assessments in a field should be done by the same person, during the same season and under similar soil moisture conditions.
- For better assessments, base sampling on variability in the field such as soil, soil moisture and yield.
- Examine the distribution of indicator values. Even if most of the indicators are scored 10 (healthy), the soil may still have serious problems.
- Careful consideration should be used to identify the cause of the problem(s).
- Impaired properties may need immediate action and should be closely monitored.
- Keep completed soil health cards on file for future reference.
- For more information on soil health, contact your local USDA Natural Resources Conservation Service (NRCS) office, county agent, agribusiness or the NRCS Soil Health website

http://www.nrcs.usda.gov/wps/portal/nrcs/site/tn/home/

Soil Health Card for Tennessee Producers

A Locally Adapted Tool
Designed by Producers for Producers

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

What is Soil Health?

The terms “soil quality” and “soil health” are used interchangeably. However, soil health refers to the function of the soil as a living ecosystem to support plants and animals. Humans also benefit from improved soil function.

Soil health is very important to all people. Healthy soil absorbs and holds more water, and has better physical, chemical, and biological properties. If we have good soil health, we will have productive land, good air and water quality as well as a healthy environment.

How to Improve Soil Health

Management greatly affects soil health. Farmers throughout Tennessee are increasing the amount of soil organic matter in their land and improving the soil’s health and function by following these basic principles of soil health:

1. Minimize disturbance due to tillage, overgrazing and traffic
2. Diversify the soil microbes that support plant growth by increasing plant diversity through crop rotation and multispecies cover crops and forage plantings
3. Keep living roots growing throughout the year to provide food for soil microbes and reap the benefits of their presence
4. Keep the soil covered as much as possilbe to conserve soil moisture, reduce soil temperature, prevent soil erosion and suppress weed growth.
5. Consider adding livestock, in a managed grazing system, to a row crop system in order to increase the cycling of plant nutrients
6. Talk with farmers using conservation tillage or managed grazing systems. They can give you some ideas about how they are changing the health of their row crop or grazing land.

About this Card

The soil health card was designed and adapted for local use. Originally, it was developed by farmers in partnership with the Georgia Conservation Tillage Alliance. It has been modified for use on all landuses in Tennessee.

It was developed by and for producers to identify where improvements could be made and to evaluate the effect of changes in management on soil health. Assessments are about quality and not absolute measures.

Note the before and after conditions in the field to record long-term improvements in soil health.

In addition to farmers, the card can also be used by soil conservationists, educators, students and garden clubs

How to Use the Tennessee Soil Health Card

Tools Required: A shovel and a soil probe, or wire flag

- Turn over a shovel full of soil (about 6-8" deep) and rate each indicator by making an **"X"** or shading out the box that best represents the value for that indicator.
- Determine soil compaction by simply pushing the probe or wire flag into undisturbed soil and noting the resistance.

Date: _____ Evaluation by: _____ County: _____ Farm: _____ Field: _____

Soil Moisture Level (check one): Good for planting: ____; Too wet for planting: _____; Too dry for planting _____.

Goal and Management: _____

Landuse Rotation for: Crops: Tillage and crop rotation; Pasture: Begin and end height and average rotation; Hay: Cutting height and number of cuttings/year; Forest: grazed or not, last harvest

Enter "Landuse Rotation" information: _____

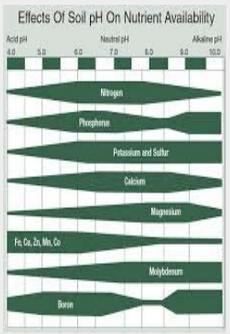
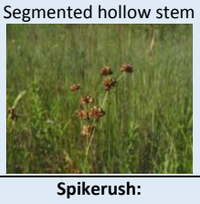
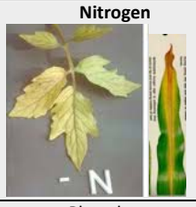
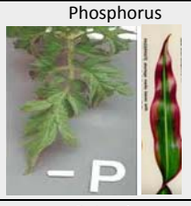
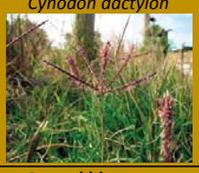
	Indicator	*Is the soil Functioning?*	→ Preferred 1/									Indicator Values		
			1	2	3	4	5	6	7	8	9	10	1	5	10
1	**Cover** or Forage greater than 2"												No living or dead cover on the soil surface	50-90% of soil surface covered with living or dead cover	>90% of soil surface covered with living or dead cover
2	**Plant Vigor** (Crop Growth)												Uneven stand; stunted crop growth; discoloring common	Some uneven stand; stunted growth; slight discoloring	Even stand; vigorous & uniform crop growth
3	**Soil Erosion** (look for terracettes & pedestal erosion) 2/												Excessive soil movement by water	Some visible soil movement by water	Little or no soil erosion by water
4	**Disturbance:**												0-30% of soil surface is covered with residue	50-70% of soil surface is covered with residue or grass over rested: brown leaves shading green leaves	>70% soil surface covered with residue
5	**Plant Diversity** Crop rotation/Forage diversity												Two crops or less in rotation or one dominant forage species	3 to 4 crops with no cover crop or three forage species from 1 group	4 crops with cover crop or 4 or more forage sp. 3 groups
6	**Surface Soil Color**												White, light gray, or red	Dark gray or light brown	Dark brown or black
7	**Soil Structure** (Tilth)												Hard (cloddy, hard or crusty)	Some visible crumbly structure	Friable (crumbly)
8	**Water Infiltration** and Water Holding Capacity												Excessive runoff or ponding; Very low water holding capacity	Some runoff or ponding; Poor water holding capacity	Very little runoff/ponding; Good water holding
9	**Living Roots**/Biological Activity												Roots turning and or stunted. Little or no sign of soil life	Some living organisms or signs of soil life	Numerous signs of soil life
10	**Compaction**/Crusting (check relative to a non-traffic area)												Can **Not** push probe or wire flag into soil; crusting is prevalent	Can push probe or wire flag in soil with force; some soil crusting	Probe or flag enters soil easily; no soil crusting
11	**Soil pH** 3/												pH 1.0 lower than needed	pH 0.5 lower than needed	Proper pH for the crops(s)
12	**Soil Fertility** 3/												More than 2 elements not within UT recommendations	Two elements not within UT recommendations	All elements within UT recommendations
13	**Soil Organic Matter** 3/												<1% in a soil sample	1-2% in soil sample	>4% in a soil sample
14	**Other Indicator**(s) Chemical, Physical or Biological														

1/Ratings 1 to 10 are user determined. 2/Terracette: small drift of soil and residue; Pedestal erosion: soil standing up under residue or a rock. 3/Lab analysis needed. Soil sample depth of 6". 07/06/2015

INDICATOR PLANTS

Greg Brann, Grazing Soil Health Specialist

Indicator Plants are plants that by their presence or abundance, provide an assessment of the quality of the site. Past soil management has a dramatic effect on the plant community and the plant community doesn't change quickly so some indicator plants may persist after management has improved. Indicator plants provide insight to what is occurring below the surface but there are many factors that come into play such as previous land use or management. These can dramatically influence seed availability on the site (e.g. – a low fertility site may still have broomsedge or rabbit tobacco on it even though fertility has improved). Soil testing, rest and recovery, more cover, increased diversity, seeding or other soil management methods may be required to alter the site to the desired state. The best weed control is out-competing undesirable plants. "Manage for what you want, not for what you don't want. It takes grass to grow grass."

COMPACTED SOIL	OVER GRAZED LAND	WET OR FLOODED SOIL	LOW FERTILITY SOIL	DEFICIENCY
Low Oxygen soils: Platy layers in soil, high bulk density (poor infiltration, increased runoff)	**Lack of cover:** effects similar to compacted land – High weed population	**Low Oxygen soils:** Pore spaces become saturated or not present negatively affecting soil structure, decomposition, and chemical and biological processes	**Unbalanced Fertility:** pH below 5.1 (frequent) or above 7.3 (high pH is uncommon in TN). Often Phosphorous is limiting factor. Potassium is typically limiting on hay land	**Severe deficiency of a nutrient or pH is low and infrequently too high in TN** 
Prostrate knotweed: ***Polygonum arenastrum or aviculare*** 	**Horsenettle:** *Solanum carolinense* 	**Sedges:** ***Carex spp*****. Sedges have edges, triangular stem** 	**Rabbit tobacco:** *Pseudognaphalium obtusifolium* 	
Rushes: *Juncus spp.* 	**Bitter sneezeweed**: *Helenium amarum* 	**Rushes**: Juncus spp. Segmented hollow stem 	**Red sorrel:** *Rumex acetosella* 	**Nitrogen** 
Goosegrass: *Eleusine indica* 	**Spiny amaranth:** *Amaranthus spinosus* 	**Spikerush:** *Eleocharis spp.* 	**Poor Joe:** *Diodia virginiana* 	Phosphorus 
Bitter sneezeweed: *Helenium amarum* 	**Bermudagrass:** *Cynodon dactylon* 	**Flatsedge:** *Cyperus spp.* 	**Broomsedge:** *Andropogon virginicus* 	Potassium 
Dog fennel: *Eupatorium capillifolium* 	**Annual bluegrass:** *Poa annua* 	**Bulrush:** *Scirpus spp.* 	**Sweet vernalgrass:** *Anthoxanthum odoratum* 	Calcium 
Buttercup: *Ranunculus* 	**Kentucky bluegrass:** *Poa pratensis* 	**Virginia buttonweed:** *Diodaia Virginiana* 	**Oxeye Daisy:** *Leucanthemum vulgare* 	Magnesium 
Curly dock: *Rumex crispus* 	**Crabgrass:** *Digitaria ischaemum* 	**Smartweed:** *Persicaria spp.* 	**Panicums:** *Panicum spp.* 	Iron 
Chicory: *Cichorium spp.* 	**Ironweed:** *Vernonia gigantea* 	**Reed canarygrass:** *Phalaris arundinacea* 	**Yarrow:** *Achillea millefolium* 	Zinc 

Some Options for Mitigating Resource Concerns

The plants that grew naturally on the site are nature's way of healing the site some of them are very palatable and others are not. If these are undesirable plants you may want to terminate existing plants and plant a more desirable plant community that is adapted to the site.

Compacted Soil: More roots are needed fibrous and tap roots. Maintaining living roots all year helps. Allowing plants to recover longer between grazing and mowing improves root system. More residue helps. Resting plants during their active growing season strengthens plants. All plants help reduce issues with compaction but the following plants are renowned for improving soil Compaction. Cool season annual plants are: Forage radish and Cereal rye; perennial cool season plants: alfalfa, chicory, red clover and sweet clover. Warm season annual plants are: sorghums and warm season perennial plants: Native warm season grasses like: big bluestem, little bluestem, indiangrass, switchgrass and eastern gamagrass. Bermudagrass is tolerant of overgrazing and rather drought tolerant but doesn't have as deep a root system as natives and needs nutrients for production.

Overgrazed Land: Longer recovery between grazing improves vigor of plants. If grazing skip a paddock resting a paddock for up to 90 days in the growing season and up to 210 days in the winter. Lowering stocking rate will remove stress on the the grass, soil, livestock and you. Increasing inputs such as fertilizing, feeding, number of paddocks and rotating more often leaving minimum heights of grass for soil protection, improved infiltration, lower soil temperature and improved water management. All of these inputs reduce the impacts of overgrazing and shallow root systems. When minimum grazing heights are reached confine livestock to 20% or less of the land and feed hay till other paddocks reach a minimum height of 8" then resume grazing. It is ideal to graze a paddock for 3 days or less, not allowing livestock to take a second bite of the same plant. In general the minimum recovery time or rest period between grazings is 14 days but base the rotation on height don't graze below 4" (minimum of 4 layers of leaves).

Minimum Grazing Heights

Species	Minimum Starting Height (Layers of leaves)	Minimum Ending Height (Layers of leaves)	Notes
Tall fescue, orchardgrass, bromegrass, ryegrass and small grains	8" (8)	4" (4)	Tall fescue and annual ryegrass are tolerant of lower grazing but will produce more and regrow faster at these heights.
Bermudagrass, Crabgrass, Dallisgrass	5" (4)	2" (2)	Plants tolerant of lower grazing
Tall Upright grasses like: sorghums, millets, johnsongrass	18" (7)	8" (3 to 4)	If you graze lower they will likely not die but production will be compromised
Flat leaf plants like clovers	5" (5)	3" (3)	White clover is tolerant of close grazing and will actually increase when close grazed

Wet or Flooded: NRCS does not encourage draining land, wetlands are very important ecosystems and aquifer recharge areas. Before draining land check with your local NRCS office you could lose USDA benefits or be fined by other agencies. Don't graze or travel on wet or saturated soil. Drive only in designated areas controlling traffic. If you must enter a field when it is wet walk or use an atv also wide tires compact less that narrow tires. Forage species that are adapted to wet and flooded land are: cereal rye, hairy vetch, alsike clover, red top, alsike clover, switchgrass and eastern gamagrass.

Low Fertility Soil: A plant tissue test may be in order to determine the deficiency contact the lab prior to sending in the sample. Feeding hay on low fertility relocates nutrients to the feeding site. Move or unroll hay in a new location each time you feed. High density short duration grazing improves manure distribution which improves fertility. Adjust pH to the desired level prior to applying deficient nutrients. You can move fertility in the animal as well by grazing a fertile field then rotating to one less fertile the manure dropped will be from the more fertile field. Plants, cover and roots aid in making more nutrients actively available to plants. Plants adapted to low fertility include: Cereal rye, lespedezas and native grasses.